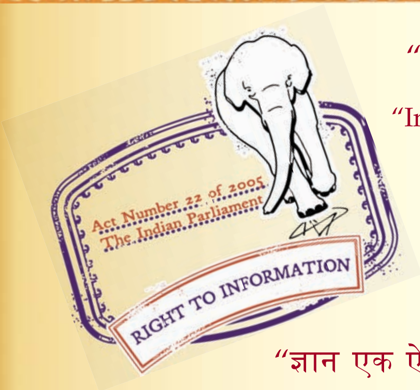
IS 10799 (1999): Irrigation Equipment - Design, Installation and Field Evaluation of Microirrigation Systems - Code of Practice [FAD 17: Farm Irrigation and Drainage Systems]



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भारतीय मानक

सिंचाई उपस्कर — सूक्ष्म सिंचाई तन्त्र का डिजाइन, संस्थापन और खेत में मूल्यांकन — रीति संहिता

(पहला पुनरीक्षण)

Indian Standard

IRRIGATION EQUIPMENT — DESIGN, INSTALLATION AND FIELD EVALUATION OF MICROIRRIGATION SYSTEMS — CODE OF PRACTICE

(First Revision)

ICS 65.060.35

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

June 1999

Price Group 7

Irrigation and Farm Drainage Equipment and System Sectional Committee, FAD 54

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Irrigation and Farm Drainage Equipment and System Sectional Committee had been approved by the Food and Agriculture Division Council.

The use of microirrigation systems in this country is increasing at a substantial rate. As the need for recommended practices for systems design and installation has been felt extensively, this standard was first prepared in 1984. With the change in the technology it was felt to revise the standard and update it with the present practices being followed. While revising the standard the procedure for field evaluation of microirrigation system has also been included.

In the preparation of this standard assistance has been derived from the following ASAE standards published by American Society of Agricultural Engineering:

ASAE	EP 405.1	Design and Installation of Microirrigation Systems, and
ASAE	EP 458	Field Evaluation of Microirrigation System.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value, should be the same as that of the specified value in this standard.

Indian Standard

IRRIGATION EQUIPMENT — DESIGN, INSTALLATION AND FIELD EVALUATION OF MICROIRRIGATION SYSTEMS — CODE OF PRACTICE

(First Revision)

1 SCOPE

This standard specifies recommendations for the design, installation, performance and procedure for field evaluation of microirrigation systems; including trickle, drip, subsurface, bubbler and spray irrigation systems.

2 DEFINITIONS

2.1 Application Efficiency, E_a

The percentage of the total water applied that is actually stored in the root zone.

2.2 Chemical Water Treatment

Chemical treatment of the water to make it acceptable for use in microirrigation systems. This may include acids, fungicides and bactericides used to prevent emitter clogging or used for *p*H adjustment.

2.3 Coefficient of Variation, V_{qs}

A statistical measure of the relative dispersion for an independent variable as defined in this code (*see* **2.22**).

2.4 Confidence Limits

A statement which relates the probability that the true value of a variable falls within the described interval.

2.5 Control Station

The control station may include facilities for water measurement, filtration, treatment, application of additives, flow and pressure control, timing of application and backflow prevention.

2.6 Crop Area

The field surface area allocated to each plant. In tree crops the tree crop area is the spacing multiplied by the row spacing.

2.7 Design Area

The specific land area which is to be irrigated by the microirrigation system.

2.8 Design Emission Uniformity

An estimate of the uniformity of emitter discharge rates throughout the system, as described by the equation in **3.5.2**.

2.9 Emitters

Device fitted to an irrigation lateral and intended to emit water in the form of drops or continuous flow at a rate not exceeding 16 l/h per outlet except during flushing.

2.9.1 *Emission Point*

Point where the water is discharged from an emitter.

2.9.2 *Line-Source Emitters*

Water is discharged from closely spaced perforations, emitters or a porous wall along the lateral line.

2.9.3 *Point-Source Emitters*

Water is discharged from emission points that are individually and relatively widely spaced, usually over 1 m. Multiple-outlet emitters discharge water at two or more emission points.

2.10 Emitter Discharge Coefficient of Variation, V_{qs}

A statistical term used to describe the variation in emitter discharge rates in a submain unit or throughout a microirrigation system for a given set of operating conditions.

2.11 Emitter Discharge Exponent

The emitter discharge exponent, x, as described by the equation $q = kh^x$, which characterizes the type of emitter. For example, an x value of 0.5 is common for orifice type emitters, whereas the x value for a pressure compensating emitter would range from 0.0 to 0.2.

2.12 Emitter Discharge Rate

The discharge rate at a given operating pressure and at a temperature of 27 °C from an individual point-source

emitter expressed as a volume per unit time or from a unit length of line-source emitter expressed as a volume per unit length per unit time.

2.13 Emitter Operating Pressure

The average operating pressure of the emitters within any simultaneously operated portion of the system.

2.14 Emitter Performance Coefficient of Variation, V_{pf}

A statistical term used to describe the variation in emitter discharge due to the combined effects of emitter manufacturer's variation, emitter wear and emitter plugging.

2.15 Evapotranspiration

The combined effects of evaporation from the soil and plant surface and transpiration from plants. Peak evapotranspiration is the maximum rate of daily evapotranspiration.

2.16 Filtration System

The assembly of independently controlled physical components used to remove suspended solids from irrigation water. This may include both pressure and gravity-type devices and such specific units as settling basins or reservoirs, screens, media beds and centrifugal force units.

2.17 Hydraulic Design Coefficient of Variation, V_{hs}

A statistical term used to describe the variation in hydraulic pressure in a submain unit or throughout a microirrigation system. Care should be taken not to confuse this term with the emitter discharge coefficient of variation due to hydraulics, V_{qh}, as defined by the equation in **4.1.3.4**.

2.18 Irrigation Deficit

The percentage of the soil volume in the root zone which is not wetted to field capacity or above (after irrigation) divided by the total potential root zone of the crop.

2.19 Lateral

The water delivery pipeline that supplies water to the emitters from the manifolds.

2.20 Main and Submain

The water delivery pipelines that supply water from the control station to the manifolds.

2.21 Manifold

The water delivery pipeline that supplies water from the submain or main to the laterals.

2.22 Manufacturer's Coefficient of Variation (C_v)

This is a measure of the variability of discharge of a random sample of a given make, model and size of emitter, as produced by the manufacturer and before any field operation of ageing has taken place.

$$C_v = \frac{s}{x}$$

where

x = the mean discharge of an emitter in the sample, and

s = the standard deviation of the discharge of the emitters in the sample

$$s = \left[\frac{\Sigma(x_i - x)^2}{n-1}\right]$$

where

x_i = the mean discharge of an emitter,

n = the number of emitters in the sample, and

i = a subscript identifying individual emitters.

If a line-source emitter is used, the individual discharges from holes on a one-meter or other specified length of emitter tape are used. This term can also be used to describe the variability in the downstream pressure from pressure control valves or the variability in discharge from flow control valves or orifices.

2.23 Microirrigation

The frequent application of small quantities of water on or below the soil surface as drops, tiny streams or miniature spray through emitters or applicators placed along a water delivery line. Microirrigation encompasses a number of methods or concepts; such as bubbler, drip, trickle, mist or spray and subsurface irrigation.

2.23.1 *Bubbler Irrigation*

The application of water to the soil surface as a small stream or fountain, where the discharge rates for point-source bubbler emitters are greater than for drip or subsurface emitters but generally less than 225 l/h. Because the emitter discharge rate normally exceeds the infiltration rate of the soil, a small basin is usually required to contain or control the water.

2.23.2 *Drip and Trickle Irrigation*

The application of water to the soil surface as drops or tiny streams through emitters. Often the terms drip and trickle irrigation are considered synonymous. For trickle and drip irrigation, discharge rates for point source emitters are generally less than 16 l/h for single-outlet emitters, and discharge rates for line-source emitters are generally less than 16 l/h/m of lateral.

2.23.3 *Spray Irrigation*

The application of water by a small spray or mist to the soil surface, where travel through the air becomes instrumental in the distribution of water. Discharge rates for point-source spray emitters are generally lower than 175 l/h.

2.23.4 *Subsurface Irrigation*

The application of water below the soil surface through emitters with discharge rates generally in the same range as drip irrigation. This method of water application is different from and not to be confused with the method where the root zone is irrigated by water table control, herein referred to as subirrigation.

2.24 Microirrigation Systems

The physical components required to apply water by microirrigation system components that may be required include the emitters, lateral lines, manifold lines, main and submain lines, filter, chemical injectors, flow control station and other necessary items.

2.25 Net Irrigation Water Requirement

Quantity of water that is required for crop production, exclusive of effective precipitation.

2.26 Peak Daily Irrigation Water Requirement

The net quantity of water needed to meet the peak daily evapotranspiration rate occurring during the growing season expressed in mm/day.

2.27 Percentage Wetting

The percentage of the soil volume in the root zone which is wetted to field capacity or above (after irrigation) divided by the total potential root zone of the crop.

2.28 Percent Area Wetted

The area wetted as a percentage of the total crop area.

2.29 Pumping Station

The pump or pumps that provide water and pressure to the system, together with all necessary appurtenances such as base, sump, screens, valves, motor controls, motor protection devices, fences and shelters.

2.30 Root Zone

The root zone of a plant is defined as the depth of soil, from which the plant extracts moisture.

2.31 Statistical Uniformity, *U*

An estimate of the uniformity of emitter discharge rates throughout an existing microirrigation system as described by the equation in **4.1.1.2**.

2.32 Submain Unit

An independently controlled irrigation unit usually covering from 1 ha to 5 ha and including a submain manifold, lateral lines and emitters.

2.33 Subunit

The main manifold and lateral pipelines which operate simultaneously and have independent flow control.

2.34 System Operating Pressure

The average operating pressure downstream from the pumping and control station where the main lines begin.

2.35 Water Additives

The addition of fertilizers, herbicides, insecticides or other additives to the water primarily for the enhancement of crop production, and sometimes as a chemical water treatment to reduce emitter clogging.

2.36 Water Amendment

The fertilizer, herbicide, insecticide or other material added to the water for the enhancement of crop production or as a chemical water treatment to reduce emitter clogging.

2.37 Wetted Area

The average irrigated soil area in a horizontal plane located at or below the emitter.

3 DESIGN, INSTALLATION, AND PERFORMANCE

3.1 System Capacity

Microirrigation systems shall have a design capacity adequate to satisfy the peak irrigation water requirement as described in **3.1.1** and **3.1.2** of each and all crops to be irrigated within the design area. The capacity shall include an allowance for water losses (evaporation, runoff, deep percolation) that may occur during application periods. The system shall have the capacity to apply a stated amount of water to the design area in a specified net operation period. The system should have a minimum design capacity sufficient to deliver the peak daily irrigation water requirements in about 90 percent of the time available or not more than 22 h of operation per day. If a system is designed with a capacity less than the peak daily irrigation water requirement, the design capacity shall be stated in writing. The principle for estimation of water requirements for installation of drip irrigation system is given in Annex A.

3.1.1 *Design According to Peak Irrigation Requirement*

Where irrigation provides all or part of the water to the crop, the system shall have the capacity to meet the

peak daily irrigation requirements of all crops irrigated within the design area. Unless field research with microirrigation systems is available, peak daily irrigation water requirements for crops determined with conventional irrigation systems should be used to determine system capacity.

3.1.2 *Special Cases*

If specified by the user (for example, economic considerations, especially in areas of frequent rainfall) and/or for special uses, the system may be designed with a capacity to apply a required volume of water, which is less than peak, to a design area in a specified net operating period.

3.2 Emitter Discharge Rate

The following conditions shall be met:

3.2.1 For drip, subsurface, and spray irrigation, the emitter discharge rate should not create runoff within the immediate application area. Small depressional ponds may develop beneath or above an emitter, but channelization to a furrow or other nearby low-lying area should be avoided. In fields with varying soil types, this criterion shall apply to the soil with the lowest infiltration rate unless it is less than 15 percent of the area irrigated.

3.2.2 For bubbler irrigation, a basin beneath the plant canopy will be required for water control. Applications shall generally be confined to the basin area.

3.2.3 Where natural precipitation and/or stored soil water is not sufficient for germination, special provisions shall be made for germination, or the microirrigation system shall apply water at a rate sufficient to adequately wet the soil to germinate seeds or establish transplants. The depth of a subsurface system for use on annual crops shall be limited by the ability of the system to germinate the seeds, unless it is stated in writing that other provisions will be required for this function.

3.2.4 Proper emitter discharge rate shall be determined and specified. Infiltration rates for different types of local, bare soils may be obtained from responsible agricultural technicians. In the absence of such advice, the proper emitter discharge rate may be estimated on the basis of past experience with similar soil types. In area field tests are recommended.

3.3 Number and Spacing of Emitters

The number and spacing of emitters along the lateral line depend upon the emitter discharge rate, system capacity, soil waterholding capacity, lateral spread of water from the emission points, crop being grown, depth of irrigated root zone, desired water application efficiency and emitter discharge variability. Information on soil water-holding capacity and effective crop rooting depth can usually be obtained from responsible agricultural technicians, or may be estimated on the basis of past experience with similar crops and soil types. The lateral spread of water may also be estimated from past experience, but in new areas field tests are recommended. The area wetted as a percent of the total crop area may range from a low of 20 percent for widely spaced crops, such as trees, to a high of over 75 percent for row crops.

3.4 Operating Pressure

The design operating pressure shall be in accordance with the recommendations of the manufacturers. The system operating pressure must compensate for pressure losses through system components and field elevation effects.

3.5 Water Application Uniformity

The water application uniformity (for nonpressure compensating emitters) is affected by the operating pressure, emitter spacing, land slope, pipeline size, emitter discharge rate and emitter discharge variability. The emitter discharge variability is due to pressure and temperature changes, manufacturing variability, ageing and clogging.

3.5.1 *Emitter Manufacturing Variability*

The expected manufacturer's coefficient of variation (C_v) should be available for new emitters operated at a constant temperature and near the design emitter operating pressure. A general guide for classifying C_v values is shown in Table 1.

Table 1 Recommended Classification of Manufacturer's Coefficient of Variation (C_v)

(*Clauses* 3.5.1 *and* 5.1.2.2)

Emitter Type	C_v Range	Classification
(1)	(2)	(3)
Point-source	< 0.05	Excellent
	0.05 to 0.07	Average
	0.07 to 0.11	Marginal
	0.11 to 0.15	Poor
	> 0.15	Unacceptable
Line-source	<0.10	Good
	0.10 to 0.20	Average
	> 0.20	Marginal to Unacceptable

3.5.2 *Design Emission Uniformity*

To estimate design emission uniformity in terms of C_v and pressure variations at the emitter, the following equation is suggested:

$$EU = 100 \left| 1.0 - \frac{1.27\, C_v}{\sqrt{n}} \right| \frac{q_m}{q_a}$$

where

EU = the design emission uniformity, percent;

n = for a point-source emitter on a perennial crop, the number of emitters per plant; for a line-source emitter on an annual or perennial row crop, either the lateral rooting diameter of the plants divided by the same unit length of lateral line used to calculate C_v or 1, which is greater;

C_v = the manufacturer's coefficient of variation for point or line-source emitters;

q_m = the minimum emitter discharge rate for the minimum pressure in the subunit, l/h; and

q_a = the average or design emitter discharge rate for the subunit, l/h.

Table 2 shows recommended ranges of EU values.

Table 2 Recommended Ranges of Design Emission Uniformity (*EU*)
(*Clause* 3.5.2)

Emitter Type	Spacing (m)	Topography	Slope, Percent	EU Range, Percent
(1)	(2)	(3)	(4)	(5)
Point source on perennial crops	> 4	Uniform Steep or undulating	< 2 > 2	90 to 95 85 to 90
Point source on perennial or semipermanent crops	< 4	Uniform Steep or undulating	< 2 > 2	85 to 90 80 to 90
Line source on annual or perennial crops	All	Uniform Steep or undulating	< 2 > 2	80 to 90 70 tc 85

3.5.3 *Allowable Pressure Variations*

The following recommendations are made to reduce pressure loss and minimize pipeline sizes in microsystems.

3.5.3.1 Pressure differences at the emitters throughout the system (or block or subunit) should be maintained in a range such that the desired design emission uniformity (EU) is obtained. For example, from the equation in **3.5.2**, with an EU of 80 percent, a C_v of 0.10, and one emitter per plant, the ratio between the minimum and average emitter discharge rate should be no less than 0.92. Since the allowable pressure loss corresponding to the minimum emitter discharge rate will differ depending on the emitter characteristics, the allowable pressure variation should be stated in writing for the specific emitter type and C_v specified.

3.5.3.2 Field shape and slope frequently dictate the most economical lateral direction. Whenever possible, laterals should be laid downslope for slopes of less than 5 percent if lateral size reduction can be attained. For steeper terrain, lateral lines should be laid along the field contour and pressure compensating emitters should be specified or pressure control devices used along downsloped laterals.

3.5.3.3 Excessive main or submain pressure differences can result in widely varying manifold or lateral takeoff pressures. In some instances, these excessive variations cannot be controlled by main or submain size alone. The only practical alternative is to design for adequate pressure at the lateral lines and properly regulate the pressures at the manifold or lateral lines. This pressure regulation may be accomplished by using automatic pressure regulators, fixed orifice or flow control pipe restrictions, or manually set valves.

3.5.3.4 Pipe sizes for mains and submains should be chosen after considering pipe costs and power costs, while keeping flow velocities within recommended limits for surge control and accounting for the effect on design emission uniformity from the resulting pressure variations.

3.6 Filtration Systems

A general design recommendation for the water filtration system should include location, size, specification of allowable suspended material sizes, types of filter or filters, and maintenance requirements.

3.6.1 *Location*

A primary filter shall be located after the pump and chemical injection point to remove both large and fine particles from the flow. Secondary filters may be used downstream from the primary filter to remove any particles which may pass through the primary filter during normal or cleaning operations. Water meters, solenoid-operated valves and final pressure regulators should follow the primary and secondary filters. Lateral-line or inline filters can be used as additional protection.

3.6.2 *Size*

Filter flow openings shall be sufficiently small to prevent the passage of unwanted particles into the system. When available, recommendations of the emitter manufacturer shall be used to select the size of the filtration system. In the absence of manufacturer's recommendations, the filter size should be based on the diameter of the emitter opening or the type and size of contaminants to be filtered. The capacity of the filter should be sufficiently large to permit the rated flow without frequent cleaning. Filters that are to be cleaned by hand should not require more than daily maintenance. The maximum permissible head loss across the filter shall be 70 kPa before filter cleaning is required.

3.6.3 *Types*

Filtration may be accomplished through the use of pressure filters (screen and media) and gravity filters (centrifugal separators, gravity screen filters and settling basins).

3.6.3.1 *Pressure screen filters*

This filter consists of a screen made of metal, plastic, or synthetic cloth enclosed in a special housing used to limit maximum particle size. The presence of algae in irrigation water tends to cause screen blockage and can considerably reduce filtering capacity. Screens are classified according to the number of openings per inch with standard wire size for each screen size. Most manufacturers recommend 150 μ to 75 μ (100 to 200 mesh) screens for emitters, but some recommend screens as coarse as 600 microns (30 mesh). Screen flow capacity should not exceed 135 l/s per square metre of screen opening.

3.6.3.2 *Media filters*

Media filters consist of fine gravel and sand of selected sizes placed in pressurized tanks. Media can lose effectiveness with time (due to rounding, etc) and should be replaced after extended usage. Media filters are not easily plugged by algae and can remove relatively large amounts of suspended solids before cleaning is needed. Cleaning is accomplished by forcing water backwards through the filter (backflushing). Media filters in current use will retain particle sizes in the range of 25 to 200 microns. In general, water flow rates through the filters should be between 10 and 18 l/s per square metre of filtration surface area. Media filters should be followed by secondary screen filter or a rinse cycle valve to prevent carryover of contaminants following the backwashing process.

3.6.3.3 *Centrifugal separators*

Sand separators, hydrocyclones or centrifugal filters remove suspended particles that have a specific gravity greater than water. These filters are ineffective in removing most organic solids. A sand separator can effectively remove a large number of sand particles and may be installed on the suction side of the pump as a prefilter to reduce pump wear.

3.6.3.4 *Settling basins*

Settling basins, ponds or reservoirs can be used as a form of pre-filtration treatment, but unless covered, the water is exposed to wind-blown contaminants and algae growth. Open reservoirs can be treated with commercially available algicides; however, care must be taken to avoid potential environmental hazards. When used, basins should be sized to limit turbulence and permit a minimum of 15 min for water to travel from the basin inlet to the pumping system intake.

3.6.3.5 *Gravity screen filters*

Gravity screen filters rely upon gravity instead of water pressure to move water through the screen. Pressure losses across gravity screen filters rarely exceed 7 kPa consequently they can be used in systems where pressure losses must be minimized. They are also effective in removing organic (that is, algae) as well as inorganic contaminants.

3.7 Flushing System

To assist in keeping sediment build-up at a minimum, automatic or hand flushing of all microirrigation pipelines is recommended on a regular time schedule. Filtration should be effective enough so that flushing of the system is needed on more frequently than once per week.

3.7.1 *Location*

Valves shall be provided at the ends of mains and submains and provisions made for flushing of lateral lines. All connections and pipeline fittings shall be large enough in diameter to facilitate flushing.

3.7.2 *Capacity*

A minimum flow velocity of 0.3 m/s is needed for flushing of lateral lines. Because only a few lateral lines can be flushed at one time, the flushing system should be adequately valved so that subunits can be flushed independently.

3.8 Chemical Water Treatment

The need for chemical water treatment depends primarily on the type of microirrigation system used and the composition of the water. Acids and bactericides are both used for prevention of emitter clogging and renovation after clogging occurs.

3.8.1 *Acids*

The least expensive acid available can be used, usually at a concentration which is sufficient to offset calcium, magnesium or iron carbonate and bicarbonate precipitation. Another method for dealing with water high in bicarbonates is to aerate the water and hold it in a reservoir until equilibrium is reached and the precipitates have settled out.

NOTE — The reduction of water *p*H may cause harmful effects on crop production if it results in lowering of *p*H of the soil. Before deciding the concentration of acid solution for lowering the *p*H, the particular crop in question should be studied.

3.8.2 *Bactericides*

Calcium hypochlorite, sodium hypochlorite, chlorine gas, or other algicides and bactericides can be added continuously or periodically at the control station to inhibit bacterial growth. Registration of these chemicals for use in microirrigation systems may be required. For high *p*H waters, acids can be injected to

adjust pH to increase the bacteria-killing property of the hypochlorites. If hypochlorite and acids are used simultaneously, they shall be injected from separate sources to avoid the possibility of generating lethal chlorine gas. Gas chlorination or hypochlorination is not recommended for water containing more than 0.4 mg/l (0.4 ppm) dissolved iron, since it can lead to the precipitation of iron that may not be filterable and may deposit in pipelines and emitters. The amount of chlorine to be added depends on the chlorine demand and the potential for bacterial emitter clogging. Where bacterial control is needed, enough chlorine should be added to have some measurable amount of free residual chlorine [at least 0.1 mg/l (0.1 ppm)] present at the ends of all lateral lines after a chemical injection period. When continuous or frequent monitoring for chlorine is not possible, it may be prudent to target for 1.0 mg/l (1.0 ppm) free chlorine at the ends of laterals to provide a sufficient safety factor to cover fluctuations in chlorine demand between monitoring times.

3.9 Fertilization System

Microirrigation systems provide a convenient method of supplying nutrient materials to the crop; however, the effects of the nutrient on the system should be considered.

3.9.1 *Nitrogen*

Ammonium sulphate, ammonium nitrate and urea have been used at low concentrations with no harmful effects on the water or irrigation system. Anhydrous ammonia, aqueous ammonia or ammophos increase pH and can cause chemical precipitation which can clog emitters, particularly with high pH water.

3.9.2 *Phosphorous*

Commonly used phosphate fertilizers tend to precipitate in irrigation waters with high hydroxyl, calcium and manganese contents. Phosphorous fertilizers can become immobilized in the soil. Phosphoric acid and water soluble organic phosphorous compounds have been successfully used in microsystems; however, common practice is to apply the phosphorous separately and not through the irrigation system.

3.9.3 *Potassium*

There are no problems associated with potassium application through microirrigation systems.

3.9.4 *Micronutrients*

Manganese, zinc, iron, copper, etc, may be applied as soluble salts through the irrigation system. These should each be injected separately and apart from other fertilizers and chemicals to avoid chemical interaction and precipitation in emitters. The effects of improper application amounts on the nutrient balance in the soil should be considered when applying micronutrients.

3.10 Injection System

The following are some of the more important considerations that shall be considered in the design of a chemical or fertilizer injection system.

3.10.1 *Injection Method and Rate*

Fertilizers may be injected by a differential pressure system, venturi injector or by pumping under pressure (pressure injected) into the irrigation water. Other chemicals such as acids, bactericides chlorine which require a constant concentration rate entering the irrigation water shall be injected by constant rate injection devices only. Chemicals shall be injected into the system after the primary filter and before the fine filter. The required rate of chemical injection depends on the initial concentration of chemical and the desired concentration of chemical to be applied during the irrigation. An injector that will operate within a range of injection rates for a number of chemicals may be desired.

3.10.2 *Concentration*

The concentration of chemicals to be injected in the irrigation water is normally very low, with ranges of 200 to 500 ppm for fertilizers and chemicals and 0.5-10 mg/l (0.5-10 ppm) for bactericides. Chemical concentrations should be routinely measured after filters and before main pipelines, and occasionally at the end of the last lateral line, to check if the entire microirrigation system is being treated.

3.10.3 *Storage Tank Capacity*

Large, low cost tanks constructed from epoxy-coated metal, plastic or fiberglass are usually practical when injection pumps are used, For a pressure differential injection system, the high pressure rated chemical tank should have enough capacity for a complete application.

3.10.4 *Contamination of Water Supply*

When the water supply or pump fails, it may be possible to have reverse flow from the injection or irrigation system. A pressure switch or other means should be used to turn off the injector pump or close solenoid operated valve on a differential pressure system so that chemicals cannot be injected when the irrigation pump is not operating. A vacuum-breaker and check valve should be placed between the water supply pump and the injection point to prevent backflow from the pipeline to the water supply. In addition, municipalities may require other backflow prevention valves at connections to municipal water lines to prevent reverse flow, particularly when water is being treated with chemicals or amendments.

3.10.5 *Resistance to Chemicals*

All hardware shall be resistant to reaction with the chemicals being injected.

3.11 Flow Monitoring

A flow measuring device shall be installed as part of the control station to aid in scheduling irrigations and monitoring system performance. Flow measurements can indicate if pressure regulation is malfunctioning, excessive leaks exist, emitters are clogging or emitter opening enlargement is occurring. Some flow measuring devices give both the accumulated flow and instantaneous flow rate. Accumulated flow over a specified period of time can be used to determine flow rate if instantaneous readings are not available.

3.12 Safety

3.12.1 The design or operation of the irrigation systems shall prevent the leaking or spraying of water on electrical lines or power units.

3.12.2 Protective devices on chemical injection equipment shall be provided to prevent contamination of the water supply or unplanned discharge of chemicals. A water source should be provided near the chemical tank for washing off chemicals if skin contact occurs. Protective clothing is advisable when handling chemicals.

3.12.3 Pumps and power units shall be set on a firm base and kept in proper alignment. Primary filters and control valves may also be mounted on a firm base.

3.12.4 Wiring and starting equipment for electrically operated plants shall comply with overload and low voltage protection requirements, and any applicable electrical codes.

3.12.5 Pumps, power units, primary filters and control valves shall be provided with protective devices. Thermostats shall be provided which stop the power units when engine or motor temperatures exceed safety points. If failure of the water supply might cause the pump to lose its prime, the motor or engine shall be properly protected. Chemical and fertilizer injection equipment shall be automatically turned off when the irrigation pump is not operating.

3.12.6 Few piping systems are operated under static conditions for long time resulting in hydraulic transient condition or Surges. A pressure Surges or water hammers, created any time, changes the flowrate in a piping system. This may be caused by valve operation, line break or rapid escape of entrapped air. In hill areas one has to be careful about this aspect and control the water hammer by using various design techniques to maintain constant downstream pressure regardless of the flowrate, controlling valve closure speed and avoiding entrapment of air during filling of water initially or after draining.

4 EVALUATION PRINCIPLES AND PROCEDURES

4.1 Water Application Uniformity

The water application uniformity is affected by the hydraulic design, topography, operating pressure, pipe size, emitter spacing and emitter discharge variability. The emitter discharge variability is due to water temperature variation, emitter manufacturer's variation, emitter wear and emitter plugging. The coefficient of variation and the statistical uniformity shall be used to evaluate the emitter discharge variation and to differentiate between hydraulic design and emitter performance variation.

4.1.1 *Statistical Uniformity*

The statistical uniformity shall be used to evaluate water application uniformity within a submain unit or thorough a microirrigation system.

4.1.1.1 The mean emitter discharge rate, q, standard deviation, S_q and coefficient of variation for a submain unit or system, V_{qs}, shall be determined as follows:

$$q = \frac{1}{n} \sum_{i=1}^{n} q_i$$

$$S_q = \left[\frac{1}{n-1} \left\{ \sum_{i=1}^{n} q_i^{\ 2} - \frac{1}{n} \left(\sum_{i=1}^{n} q_i \right)^2 \right\} \right]^{1/2}$$

$$V_{qs} = \frac{S_q}{q}$$

where

q_i = the emitter discharge rate,

n = the number of randomly selected emitters, and

i = a subscript identifying individual emitters.

4.1.1.2 The statistical uniformity of the emitter discharge rate shall be determined as follows:

$$U_s = 100\,(1 - V_{qs})$$

where

U_s = statistical uniformity of the emitter discharge rate.

4.1.1.3 The 95 percent confidence limits for a specific statistical uniformity, U_s, or emitter discharge coefficient of variation, V_{qs}, and a given random sample size, n, will be selected from Table 3. For example, given a statistical uniformity, U_s, of 90 percent as determined from a sample size of 36 observations would result in a confidence limit of $\pm$ 2.4 percent.

Table 3 95 Percent Confidence Limits, ± Percent
(*Clauses* 4.1.1.3, 4.1.2.1, 4.1.3.1 *and* 5.1.2.1)

U_s	Number of Observations, n				V_{qs}
	18	36	72	144	
(1)	(2)	(3)	(4)	(5)	(6)
90	3.5	2.4	1.7	1.2	0.1
80	7.3	5.0	3.4	2.4	0.2
70	11.5	7.8	5.4	3.8	0.3
60	16.2	10.9	7.6	5.4	0.4

4.1.1.4 The mean hydraulic pressure, h, standard deviation, S_h, and hydraulic design coefficient of variation, V_{hs} can be determined using the equations shown in **4.1.1.1** with the substitution of lateral line pressure, h, for emitter discharge, q_2, while all other variables are as previously defined.

4.1.1.5 The statistical uniformity was selected for this Indian Standard because of its ability to differentiate between the various factors affecting emitter discharge variation. In order to facilitate comparisons, a table of equivalent uniformities has been developed. Table 4 relates the statistical uniformity, U_s, to the emission uniformity, *EU*, as estimated using the lower quartile and acceptability of the design.

Table 4 Comparison of Uniformities, Percent

Method Acceptability	Statistical Uniformity (U_s)	Emission Uniformity (*EU*)
(1)	(2)	(3)
Excellent	100-95	100-94
Good	90-85	87-81
Fair	80-75	75-68
Poor	70-65	62-56
Unacceptable	< 60	< 50

4.1.2 *Emitter Discharge Variation*

The emitter discharge variation is a measure of the variation of the emitter discharge rate in a submain unit or throughout a microirrigation system. The coefficient of variation will be used to determine the emitter discharge variation using the following procedure.

4.1.2.1 Decide upon a reasonable sample size n, for the 95 percent confidence limits desired from Table 3. The number of observations required is dependent on the existing emitter discharge variation and the confidence limits desired.

4.1.2.2 Individually measure the time required to fill a constant volume container (that is, 200 ml) for n randomly selected emitters. A method for artificially selecting the random emitters would be to select an emitter randomly from each of n uniformly distributed locations in the submain unit or system.

4.1.2.3 Calculate the emitter discharge rates, l/h, for each emitter.

4.1.2.4 Calculate the emitter discharge coefficient of variation, V_{qs}, using the equations in **4.1.1.1** and the statistical uniformity using the equation in **4.1.1.2**.

4.1.2.5 A nomograph which uses approximately one-third of the data collected can also be used for a quick field evaluation. In this case, the time to fill a container (that is, 100 ml or 200 ml bottle) can be used in place of the emitter discharge rate to determine the statistical uniformity. Using this technique, the time to fill the randomly placed container, T_{Max} and T_{Min}, can be calculated as the sum of the highest one-sixth and lowest one-sixth of the emitter discharge times, respectively. The emitter discharge variation can then be determined using Fig. 1. In the case of plugged emitters the equations referred to in **4.1.2.4** and found in **4.1.1.1** and **4.1.1.2** must be used.

4.1.2.6 The number of emitters per plant may affect the actual emitter discharge coefficient of variation, V_{qs}, due to the overlapping nature of the variance. For this situation the emitter discharge coefficient of variation, V_{qs} shall be adjusted by dividing V_{qs} by the square root of the number of emitters per plant to obtain the corrected emitter discharge coefficient of variation, V_{qs}, and the corrected statistical uniformity, U_s, will result.

4.1.3 *Hydraulic Variation*

The hydraulic variation is a measure of the variation in emitter discharge rate due to hydraulic design and emitter type. The coefficient of variation will be used to determine the variations in hydraulic pressure in a microirrigation submain unit or throughout a microirrigation system. The emitter discharge exponent is then used to calculate the emitter discharge coefficient of variation due to hydraulics using the following procedure.

4.1.3.1 Decide upon a reasonable sample size, n, for the 95 percent confidence limits desired (*see* Table 3). The number of observations required is dependent on the existing emitter discharge variation and the confidence limit desired.

4.1.3.2 Individually measure the emitter pressure for n randomly selected emitters. A method for artificially selecting the random emitters would be to select one emitter from each of n uniformly distributed locations in a submain unit or system.

4.1.3.3 Calculate the hydraulic design coefficient of variation V_{hs} for the pressure data as described in **4.1.1.4**

4.1.3.4 Calculate the emitter discharge coefficient of variation due to hydraulics by the equation:

$$V_{qh} = x\ V_{hs}$$

where

V_{qh} = the emitter discharge coefficient of variation due to hydraulics, and

x = the emitter discharge exponent.

4.1.3.5 A simplified graphical technique which uses approximately one-third of the data collected can be used for quick field evaluations. In this case, the emitter pressures can be used in place of the emitter discharge rate to determine the statistical uniformity. Using the same technique described in **4.1.2.5**, the randomly selected pressure data can be used to calculate P_{Max} and P_{Min}. The hydraulic design coefficient of variation can be determined using Fig. 1. In the case of plugged emitters, the procedures in **4.1.2.4** must be used.

4.1.3.6 When using the graphical technique presented in **4.1.3.5**, the emitter discharge coefficient of variation due to hydraulics, V_{hs}, must be adjusted using the equation in **4.1.3.4** before it can be used to determine the statistical uniformity of emitter discharge due to hydraulics.

4.1.4 *Emitter Performance Variation*

Emitter performance variation is a measure of emitter discharge variability due to water temperature, emitter manufacturer's variation, emitter wear and emitter plugging. The emitter performance coefficient of variation shall be determined using the previously collected discharge and pressure data and the following procedure.

4.1.4.1 Calculate the emitter performance coefficient of variation using the previously determined emitter discharge coefficient of variation, the emitter discharge coefficient of variation due to hydraulics and the following equation:

$$V_{pf} = (V_{qs}^2 - V_{qh}^2)^{1/2}$$

where

V_{pf} = emitter performance coefficient of variation,

V_{qs} = emitter discharge coefficient of variation, and

V_{qh} = emitter discharge coefficient of variation due to hydraulics.

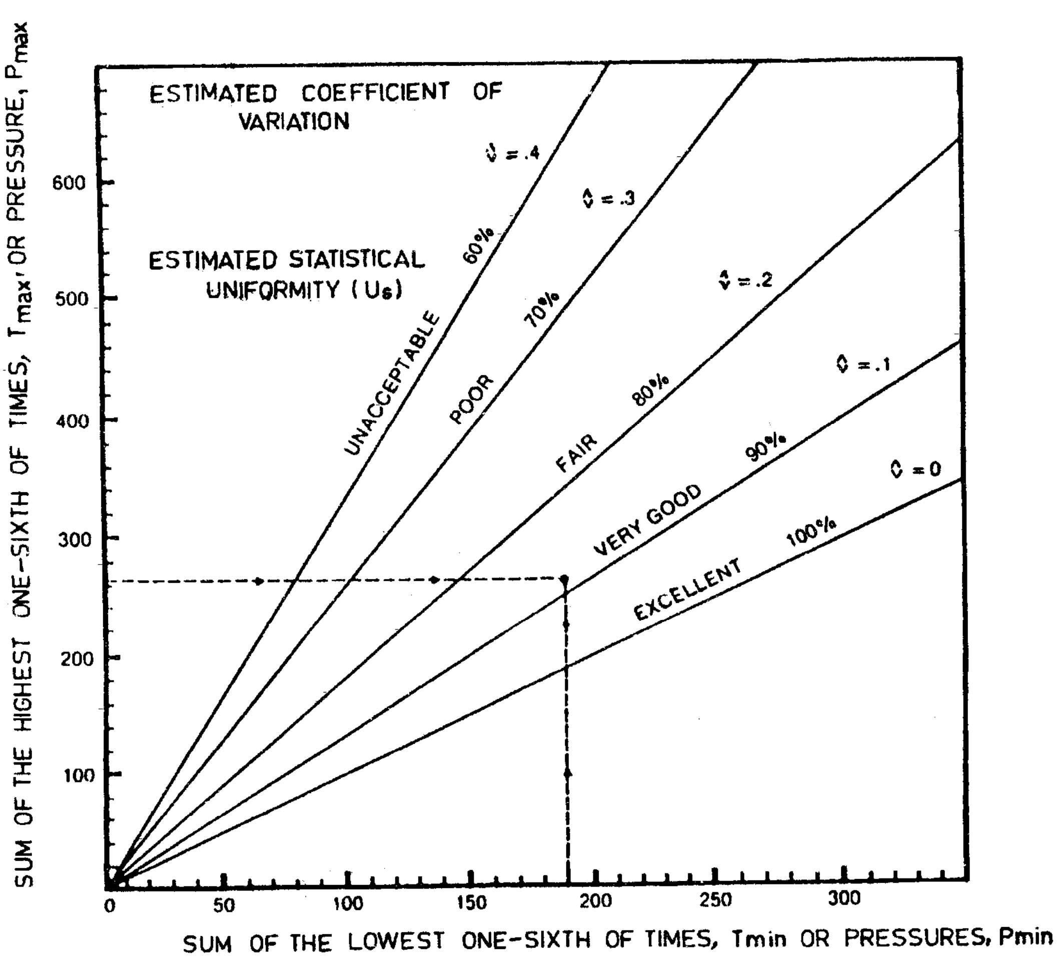

FIG. 1 STATISTICAL UNIFORMITY NOMOGRAPH

4.1.4.2 A nomograph for determining the emitter performance coefficient of variation is shown in Fig. 2.

4.1.4.3 If the original emitter performance coefficient of variation is excessively high (greater than 0.2 or 20 percent) due to emitter wear and plugging, it is recommended that additional emitter flow and pressure data be collected. If the emitter performance coefficient of variation is still excessively high, it is recommended that emitter cleaning and replacement precede further evaluation.

4.2 Water Application Efficiency

The adequacy of soil moisture distribution and the resulting application efficiency are two very important components of a complete microirrigation system evaluation. The application efficiency is affected by the plant root zone, irrigation application rate, water application uniformity and allowable irrigation deficit.

4.2.1 *Maximum Application Depth*

The maximum irrigation depth, I_{Max}, will be used to calculate the application efficiency, E_a, and shall be determined using the following equation:

$$I_{Max} = y\,(AWC)\,\frac{ZP}{100}$$

where

y = the percentage of AWC to be depleted before irrigation;

AWC = the available water holding capacity of the soil, mm/m;

Z = the soil depth (root zone, m); and

P = the wetted volume as a proportion of the total.

4.2.1.1 For field evaluation purposes, the maximum net irrigation depth, I_{Max}, is converted to required irrigation volume, V_m when multiplied by the irrigated area.

4.2.2 *Irrigation Deficit*

The percentage irrigation deficit, P_d, is dependent upon the maximum application depth, the emitter discharge coefficient of variation, V_{gs}, and the actual irrigation application. Fig. 3 illustrates the relationship of the above variables as they relate to the irrigation deficit for a normal distribution.

4.2.3 *Application Efficiency*

The application efficiency, E_a, of an irrigation system is defined as the percentage of total water applied that is actually stored in the crop root zone. When the root zone is fully irrigated based on the required irrigation volume, then the application efficiency shall be determined using the following equation:

$$E_a = 100\left[\frac{V_r\,(1-P_d)}{V_a}\right] = 100\left[\frac{V_r\,(1-P_d)}{3\,600\;Q_a T}\right]$$

where

V_r = required irrigation volume, m^3;

V_a = total amount of water applied, m^3;

$(1-P_d)$= percent or root zone irrigated;

Q_a = actual discharge into the system, m^3/s; and

T = irrigation time in hours, h.

4.2.4 *Statistical Uniformity*

The relationship between the statistical uniformity, U_s, the irrigation deficit, P_d, and the application efficiency, E_a, is shown in Fig. 4.

4.3 Filtration Systems

Depending upon the source of water for the irrigation system, the filtration system may include a single or combination of screen, media and centrifugal filters. The field evaluation of microirrigation systems should include a determination of removal efficiency and pressure differential across the filter. The effectiveness of the filtration system can be indirectly assessed by evaluating the degree of emitter plugging. In order to maintain a record of the filtration efficiency, the data in **4.3.1.2** and **4.3.1.3** should be recorded.

4.3.1 *Removal Efficiency*

The removal efficiency, E_r, of a filtration system shall be determined by the following equation:

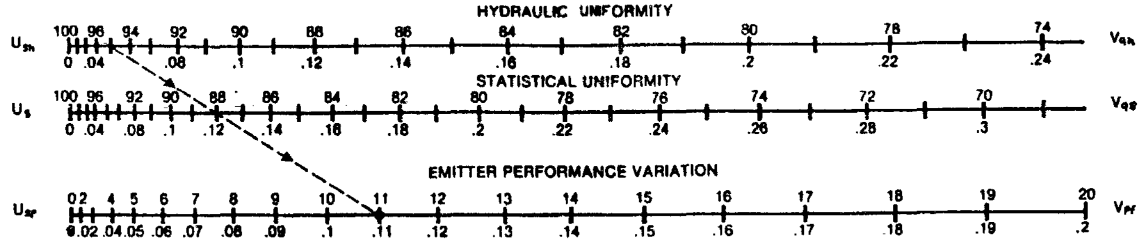

FIG. 2 EMITTER PERFORMANCE NOMOGRAPH

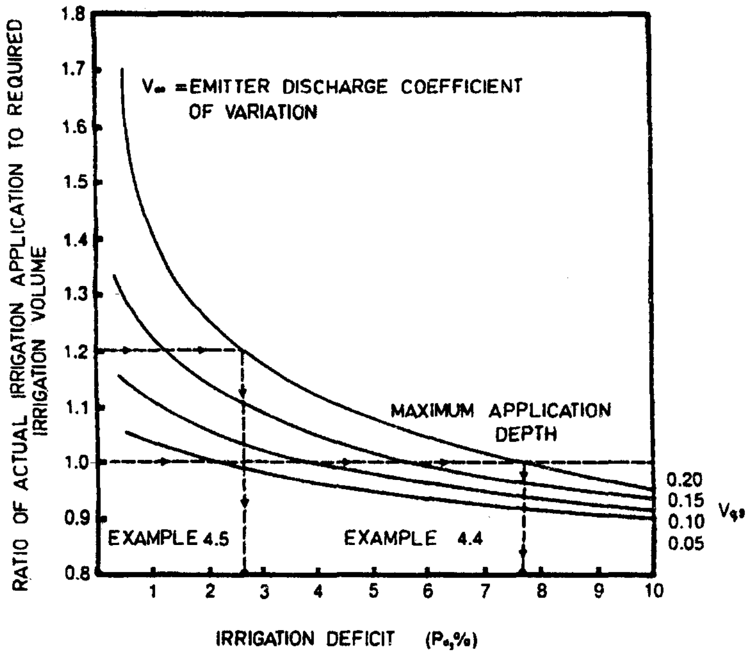

FIG. 3 IRRIGATION APPLICATION BASED UPON THE IRRIGATION DEFICIT, P_d, AND THE EMITTER DISCHARGE COEFFICIENT OF VARIATION, V_{qs}, AS PERCENTAGE OF THE TOTAL IRRIGATION VOLUME

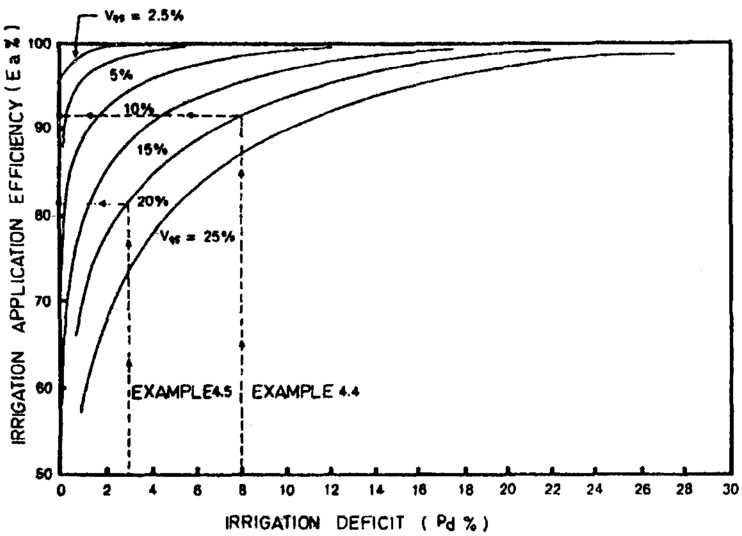

FIG. 4 APPLICATION EFFICIENCY BASED UPON THE IRRIGATION DEFICIT, P_d, AND THE EMITTER DISCHARGE COEFFICIENT OF VARIATION, V_{qs}

$$E_r = 100\left[1 - \frac{S_{out}}{S_{in}}\right]$$

where

S_{out} = the concentration of suspended solids, mg/l, in filter outlet; and

S_{in} = the concentration of suspended solids, mg/l, in filter inlet.

4.3.1.1 The definition in **4.3.1** can be used for individual constituents such as suspended solids.

4.3.1.2 Water samples shall be taken before and after the filter, 30 min after start-up to determine removal efficiency.

4.3.1.3 The time of the season that the water sample (or samples) are taken may affect the outcome of this evaluation. For this reason the time of year should be

recorded as well as any special considerations related to water quality.

4.3.2 *Pressure Differential*

The differential pressure (inlet pressure minus outlet pressure) before and after filter backflushing takes place shall be recorded. If the differential pressure after backflushing significantly exceeds the filter manufacturer's specifications, the source of this excess differential needs to be found. Excess pressure differential may be caused by insufficient flushing flow rates or time, plugged media underdrains, screens partially plugged by particles which need to be removed manually or other problems which will need to be resolved. Inversely, if the differential pressure is constantly very low, then the filter should be checked for defective screens, worn seals or inoperable flush valves.

4.3.3 *Emitter Plugging*

The amount of emitter plugging is an indirect measure for assessing the effectiveness of a microirrigation filtration system. The possible sources of emitter plugging are physical, chemical and biological in nature. In addition, the degree of emitter plugging can be used as a measure of the effectiveness of preventative practices such as chemical water treatment.

4.3.3.1 Calculate the effect of emitter plugging on the coefficient of variation by using the previously determined emitter discharge coefficient of variation, V_{qs}, the proportion (decimal) of emitters completely plugged, C, and the following equation:

$$V_{qp} = \left[\frac{1}{(1-C)} \left(V_{qs}^2 + 1\right) - 1 \right]^{1/2}$$

where

V_{qp} = the emitter discharge coefficient of variation including emitter plugging, and

$(1 - C)$ = the proportion (decimal) of emitters openly flowing.

4.3.3.2 A simplified graphical technique for determining the effect of emitter plugging on the statistical uniformity can be found in Fig. 5.

5 EXAMPLE PROCEDURES

5.1 Estimate the emitter discharge variation as represented by the statistical uniformity, U_s, for a microirrigation submain unit with the following field data.

5.1.1 *Given*

Time (seconds) to fill a 100 ml container from individual emitters: 64, 79, 67, 71, 75, 81, 68, 85, 75, 69, 85, 77, 89, 68, 81, 90, 65, 61.

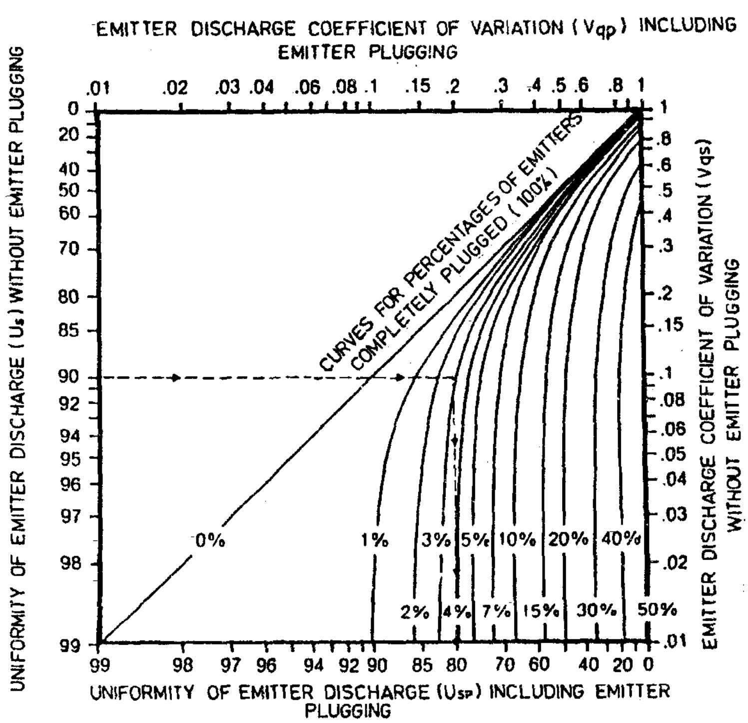

FIG. 5 RELATIONSHIP BETWEEN EMITTER PLUGGING AND THE STATISTICAL UNIFORMITY OF EMITTER DISCHARGE, U_{sp}, INCLUDING EMITTER PLUGGING

5.1.2 *Solution*

5.1.2.1 *Direct calculation method*

Step 1 — Calculate the flow rates : (ml/s) using the above data
q_i = 100 ml per 64 s = 1.56 ml/s, etc.

Step 2 — Calculate the mean standard deviation and coefficient of variation using the equation in **4.1.1.2**.

Ans: — q = 1.35 ml/s, S_q = 0.159 ml/s
V_{qs} = 0.118

Step 3 — Calculate the statistical uniformity using the equation in **4.1.1.2** and determine the confidence limit from Table 3.

Ans: — U_s = 88 ± 3 percent

5.1.2.2 *Graphical solution method*

Step 1 — Calculating T_{Max} and T_{Min} using the three highest and three lowest times
T_{Max} = 85 + 89 + 90 = 264
T_{Min} = 64 + 65 + 61 = 190

Ans: — T_{Max} = 264, T_{Min} = 190

Step 2 — Use Fig. 1 to determine the statistical uniformity, and Table 1 to determine the confidence limits.

Ans: — U_s = 88 ± 3 percent

5.2 Estimate the hydraulic variation. V_{hs}, and the statistical uniformity due to hydraulics, U_s, for a microirrigation submain unit.

5.2.1 *Given*

An emitter discharge exponent of x = 0.4 and the following field data. Pressure head in meters of water at individual emitters: 10.20, 9.98, 8.80, 8.50, 10.18, 9.01, 7.59, 10.10, 9.43, 9.75, 10.07, 8.37, 7.92, 10.07, 9.25, 10.50, 9.43, 8.97.

5.2.2 *Solution*

5.2.2.1 *Direct calculation method*

Step 1 — Calculate the mean, standard deviation and coefficient of variation using the equation in **4.1.1.2**.

Ans: — h = 9.31 ml, S_h = 0.85 m, V_{hs} = 0.091

Step 2 — Use the equation in **4.1.3.4** and **4.1.1.2** to determine the emitter discharge coefficient of variation and the statistical uniformity due to hydraulics for x = 0.4.
V_{qh} = 0.4 (0.091) = 0.036
U_s = 100 (1–0.036) = 96.4

Ans: — V_{qh} = 3.6 percent, U_s = 96.4 ± 3 percent

5.2.2.2 *Graphical Solution Method*

Step 1 — Calculate P_{Max} and P_{Min} using the three highest and three lowest pressures.
P_{Max} = 10.50 + 10.20 + 10.18 = 30.88
P_{Min} = 7.59 + 7.92 + 8.37 = 23.88

Ans: — P_{Max} = 30.88. P_{Min} = 23.88

Step 2 — Use Fig.1 to determine the hydraulic design coefficient of variation.

Ans: — V_{hs} = 0.09 or 9 percent

Step 3 — Use the equations in **4.1.1.2** and **4.1.3.4** to determine the emitter discharge coefficient of variation and statistical uniformity due to hydraulics for x = 0.4.
V_{qh} = 0.4 (0.09) = 0.036
U_s = 100 (1–0.036) = 96.4 percent

Ans: — V_{qh} = 3.6 percent. U_s = 96.4 ± 3 percent

5.2.3 To facilitate the use of Fig.1, P_{Max} and P_{Min} may be multiplied by a factor of 10.

5.3 Estimate the Percentage Variation Due to Emitter Performance

5.3.1 *Given* — The total statistical uniformity of 90 percent (*see* Example in **5.1**, and the statistical uniformity due to hydraulic of 96.4 percent (*see* Example in **5.2**).

5.3.2 *Solution*

Step 1 — Use the equation in **4.1.4.1** or Fig. 2 to determine the emitter performance variation.

Ans: — V_{pf} = 0.112 or 11.2 percent

5.4 Determine the application efficiency, E_a, and the percentage deficit, P_d, when the irrigation application is equal to the required irrigation volume for the following submain unit.

5.4.1 *Given* — The statistical uniformity, U_s, for a microirrigation submain unit is 80 percent (V_{qs} = 0.2).

5.4.2 *Solution*

Step 1 — From Fig. 3 the irrigation deficit for this situation can be found.

Ans: — P_d = 8 percent

Step 2 — Calculate the application efficiency using the equation in **4.2.3** or Fig. 4.

Ans: — E_a = 32 percent.

5.5 Determine the percent deficit, P_d, and the application efficiency, E_a, when the irrigation application is 1.2 times the required irrigation volume. Compare with example in **5.4**.

5.5.1 *Given* — The total statistical uniformity, U_s, for a microirrigation submain unit as 80 percent (V_{qs} = 0.20).

5.5.2 *Solution*

Step 1 — Determine the percent deficit for V_{qs} = 0.20 and a required irrigation application factor of 1.2 using Fig. 3.

Ans: — P_d = 3 percent

Step 2 — Determine the application efficiency of the irrigation using Fig. 4.

Ans: — $E_a = 82$ percent

5.5.3 The application efficiency in this example is less than that found in the example in **5.4** because over irrigation to make up for a large irrigation deficit or a low system uniformity decreases the application efficiency.

5.6 Determine the removal efficiency, E_r, of a 200 mesh screen filter system used in microirrigation for the removal of very fine sand.

5.6.1 *Given* — The field test results indicate the unfiltered water contains 20 mg/l greater than 75 µm material and the filtered water contains 15 mg/l greater than 75 µm material.

5.6.2 *Solution*

Step 1 — Using the equation in **4.3.1**, the removal efficiency can be calculated.

Ans: — $E_r = 25$ percent

5.7 Determine the uniformity of emitter discharge including emitter plugging, U_{sp}, for a drip irrigation submain unit.

5.7.1 *Given* — The uniformity of emitter discharge, U_s, without emitter plugging is 90 percent ($V_{qs} = 0.1$), and the emitter plugging rate is 3 percent for complete plugging.

5.7.2 *Solution*

Step 1 — Determine the uniformity of emitter discharge using the equation in **4.3.3.1** or Fig. 5.

Ans: — $U_{sp} = 80$ percent ($V_{qp} = 0.2$)

6 REPORTING OF RESULTS

6.1 Irrigation System Description

The following information shall be reported.

6.1.1 Irrigation system location, farm address and irrigated parcel location.

6.1.2 Crops irrigated, variety, spacing, age and rooting depth.

6.1.3 Soil type, description, water holding capacity, infiltration rate and total irrigated area.

6.1.4 Topography, major land slopes, and elevation differences between the water source, pumping station and irrigated area.

6.1.5 Water supply, water source, pumping station, system capacity and available pressure.

6.1.6 Control station, water measurement, filtration, treatment, addition of amendments, pressure control and timing of application.

6.1.7 Mainline material, size, length, installation depth and differential elevation to submain units under investigation.

6.1.8 Submain manifold material, size, pressure control, length, lateral spacing, installation depth and major slope.

6.1.9 Lateral line material, size, length, emitter spacing, installation depth and major slope.

6.1.10 Emitter type, manufacturer, size and installation depth.

6.2 Evaluation Data Collection

The following information shall be collected and reported.

6.2.1 Water supply, mainline flow rate and pressure at the water source.

6.2.2 Irrigation practice, allowable deficit, irrigation frequency and duration.

6.2.3 Submain manifold flow rate and pressure at the head of the manifold.

6.2.4 Emitter discharge time, rate and pressure for n random locations in the microirrigation system or submain unit.

6.2.5 Filtration efficiency, inlet water sample, outlet water sample, differential pressure across the filter and rate of percentage of emitter plugging.

6.3 Evaluation Analysis Results

The following results shall be reported.

6.3.1 *System Capacity and Design*

A statement regarding the adequacy of the existing system design and its conformance with **3** of this standard, shall be made based upon the irrigation system description data.

6.3.2 *Water Application Uniformity*

Based upon the emitter discharge and pressure data collected, the submain unit or microirrigation systems statistical uniformity, U_s, hydraulic variation, V_{qh}, and emitter performance variation, V_{pf}, shall be reported. In addition, a statement regarding the adequacy of the various system components based upon the interpretation guidelines found in **6.4** shall be reported.

6.3.3 *Water Application Efficiency*

The results of the water application efficiency, E_a, determination shall be reported. In addition, a statement regarding the current irrigation practices, including frequency and duration of irrigation, shall be made.

6.3.4 *Filter System Performance*

Based upon the data collected regarding the irrigation system filter, a statement regarding the removal efficiency, E_r, pressure differential and emitter plugging rates shall be reported.

6.4 Evaluation Interpretation Guidelines

The following guidelines will be used to report the adequacy of the irrigation system based on the evaluation results.

6.4.1 *Statistical Uniformity*

The criteria for an acceptable statistical uniformity, U_s, are 90 percent or greater, excellent; 80 percent to 90 percent, very good; 70 percent to 80 percent, fair; 60 percent to 70 percent, poor, and less than 60 percent, unacceptable. A statistical uniformity of 80 percent or greater shall be required before fertilizer injection through the microirrigation system is recommended. Possible remedies for improving the statistical uniformity include increasing the number of emitters per plant and/or improving the hydraulic and emitter performance variation.

6.4.2 *Hydraulic Variation*

The criteria for an acceptable coefficient of hydraulic variation, V_{hs}, are 10 percent or less, excellent; 10 percent to 20 percent, very good; 20 percent to 30 percent, fair; 30 percent to 40 percent, poor, and greater than 40 percent, unacceptable. Possible remedies for improving the hydraulic variation include readjustment of pressure regulation devices, repair or removal of pinched lateral lines and the redesign of the hydraulic system.

6.4.3 *Emitter Performance Variation*

The criteria for emitter performance variation, V_{ps}, are 5 percent or less, excellent; 5 percent to 10 percent, very good; 10 percent to 15 percent, fair; 15 percent to 20 percent, poor; and greater than 20 percent unacceptable. Possible remedies for improved emitter performance include cleaning plugged emitters and replacing poorly performing emitters.

ANNEX A

(*Clause* 3.1)

PRINCIPLES FOR ESTIMATION OF WATER REQUIREMENT FOR INSTALLATION OF DRIP IRRIGATION SYSTEM

A-1 ESTIMATION OF QUANTITY OF WATER

To irrigate an area by drip irrigation system sufficient quantity and rate of water should be made available at that place. To estimate the minimum quantity of water for meeting the irrigation water requirement of any area, the following steps are required.

A-1.1 Collection of General Information

General information on water source, crops to be grown, topographic conditions, type and texture of soil and climatic data are essential for designing the drip irrigation system.

A-1.2 Layout of the Field

The layout of the field by giving the path and lengths of main line, sub-main line and lateral lines in meters to connect water source with the existing/planned crop in the area must be worked out.

A-1.3 Crop Water Requirement

Water requirement of crops (WR) is a function of plants, surface area covered by plants, evapotranspiration rate. Irrigation water requirement has to be calculated for different seasons. The maximum discharge required during any one of the three seasons is adopted for design purposes. The daily water requirement for fully grown plants can be calculated as under:

$$V = E_p \times K_c \times K_p \times W_p \times S_p$$

Net depth of irrigation to be applied (V_n) = $V R_e \times S_p$

The total water requirement of the farm plot would be $V_n \times$ No. of plants.

where

V = the water requirement (lpd plant);
E_p = the pan evaporation (mm/day);
K_c = the crop factor;
K_p = the pan factor;
W_p = the wetted area (0.3 for widely spaced crops and 0.9 for closely spaced crops);
S_p = the spacing of crops/plant, (m^2); and
R_e = the effective rainfall (mm) and A is the area of the plot (m^2).

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Review of Indian Standards

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This Indian Standard has been developed from Doc: No. FAD 54 (579).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at Simco Printing Press, Delhi, India